Quiz 1

NAME: _____ **SCORE:** _____

Subject: Relativity
Date: Wednesday 08 February 2023
Duration: 60 minutes
Credits: 16 points, each question is one point.

This quiz consists of closed-book concept questions and short problems. Provide answers to the following items.

1. Give an example of a non inertial reference frame.

   An accelerating car

2. Briefly explain what does Newtonian relativity mean?

   Newtons laws of motion are the same in all inertial systems. There is no way of determining an absolute velocity frame -> there is only relative velocity between inertial frames

3. What is the problem with Newtonian relativity?

   Electromagnetism is not invariant under Galilean transformation. Experiments at high velocities disagree with the classical theory

4. What is the definition of an invariant quantity? Name an example for the Galilean transformation and one for the Lorentz transformation.

   An invariant quantity doesn't change under transformation between inertial frames.
   Galilean example: time, mass, acceleration etc...
   Lorentz example: speed of light, electric charge etc...

5. What is the "proper" length of an object.

   The length that we measure for an object in an ~~rest frame~~ inertial frame where the object is at rest.

6. Briefly explain the Michelson-Morley experiment: What was the goal of the experiment? What method did it use? What was the result?

The Michelson-Morley experiment aimed to measure the change in the speed of light in a moving inertial frame (Earth relative to the ether frame) They used an interferometer with 2 perpendicular arms. ~~That~~ The measurment was performed at several times ~~and~~ during the day and the year and the instrument was rotated. The result was no change in the speed of light with respect to the theorethical ether frame. => no ether frame

7. Name one of the alternative explanation of the Michelson-Morley experiment. Briefly explain what the idea was, and what was the problem with the theory.

- The Lorentz-Fitzgerald contraction hypothesis: all bodies contract their lengths in the direction of motion. Issue doesn't explain M-M experiment with different arm lengths.
- Ether drag: ether attached to bodies, issue: stellar abernation, Fizeau coeffici
- modified electrodynamics: speed of light depends on the velocity of the source, issue: M-M with light from the Sun or double star systems

8. What are the two postulates of special relativity?

- The laws of pysics are the same in all inertial systems
- The speed of light in vacuum has the same value in all inertial systems.

9. What other assumption did we make to deduce the Lorentz transformations in addition to the two postulates of special relativity?

Space and time are homogenious

10. Is it true that two events which occur at the same time and at the same place will occur simultaneous for another observer? Briefly explain.

yes, because they happen at the same time and place.

11. Why is simultaneity important for the measurement of the length of an object?

If an object is moving its length can change compared to when the object is at rest. If we do not observe the length at an instantaneous time ~~we with~~ the object may move by the time of the second measurement.

12. If we would like to synchronise two clocks with a signal which signal would be better to use, a sound signal or a light signal? Shortly explain.

light: - light doesn't need a medium to propagate, sound does need a medium
- light propagates faster than sound

13. Two moving clocks appear to be out of synchronisation by an amount of $L'v/C^2$ where L' is the distance between the clocks. Does the sign of the effect change if we reverse the direction of the motion of the clocks (we change v to $-v$)?

if we change v to $-v$ the sign of the expression changes $\Rightarrow \frac{L'v}{c^2} \Rightarrow -\frac{L'v}{c^2}$

14. If an event occurs in S at x=200 km, y=20 km, z=2 km, t= 5 $\times 10^{-6}$ s. And S' frames moves with a relative velocity of v=0.92c compared to S along the x-x' axis and the origins coincide at t=t'=0. What are the coordinates x', y', z', t' in the S' frame?

$c = 3 \cdot 10^8$ m/s

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{2 \cdot 10^5 - 0.92c \cdot 5 \cdot 10^{-6}}{\sqrt{1 - \frac{0.92^2 c^2}{c^2}}} = 506789.221 \text{ m}$$

$y' = y = 20000$ m

$z' = z = 2000$ m

$$t' = \frac{t - \left(\frac{v}{c^2}\right)x}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{5 \cdot 10^{-6} - \left(\frac{0.92c}{c^2}\right) \cdot 2 \cdot 10^5}{\sqrt{1 - \frac{0.92^2 c^2}{c^2}}} = -0.0015 \text{ s}$$

15. At what speed v will the Galilean and Lorentz transformation differ for the expression of x by 0.1, 1 and 10 percent?

$$\frac{L-G}{G} = \frac{L}{G} - 1 = \frac{1}{\sqrt{1-\beta^2}} - 1 = 0.001 \rightarrow \frac{1}{1.001} = \sqrt{1-\beta^2} \Rightarrow \beta = \sqrt{1-\left(\frac{1}{1.001}\right)^2}$$

0.1% $\Rightarrow 0.04\,c = 0.13 \cdot 10^8 \frac{m}{s}$

1% $\Rightarrow 0.14\,c = 0.42 \cdot 10^8 \frac{m}{s}$

10% $\Rightarrow 0.416\,c = 1.2 \cdot 10^8 \frac{m}{s}$

16. As seen from the inertial frame S an event occurs at point A on the x axis and then 10^{-6}s later an event occurs at point B further on the x-axis. A and B are 600 m apart as seen in the S frame. Does there exist another inertial system S' moving with speed v < c parallel to the x-axis such that the two event appear to be simultaneous in S'? If this is the case, what is the speed v and the direction of motion compared to S for the S' system? What is the separation of locations A and B according to S'?

S

$x_1 = 0$

$x_2 = 600\,m$

$t_1 = 0$

$t_2 = 10^{-6}\,s$

S' $\rightarrow v = ?$

$$t' = \frac{t - \left(\frac{v}{c^2}\right)x}{\sqrt{1-\frac{v^2}{c^2}}} \qquad \Delta t' = 0 \Rightarrow t_1' = 0, \; t_2' = 0$$

$$t_2' = \frac{t_2 - \left(\frac{v}{c^2}\right)x_2}{\sqrt{1-\frac{v^2}{c^2}}} = 0$$

$$t_2 - \left(\frac{v}{c^2}\right)x_2 = 0$$

$$t_2 = \frac{v}{c^2}x_2$$

$$\frac{t_2 \cdot c}{x_2} = \frac{v}{c} = \frac{\cancel{600}\,10^{-6} \cdot 3 \cdot 10^8}{600} = \frac{3 \cdot 10^2}{6 \cdot 10^2} = \frac{1}{2}$$

$$\Rightarrow \boxed{v = \frac{1}{2}c}$$

$$x_2' = \frac{x_2 - v t_2}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{600\,m - \frac{c}{2} \cdot 10^{-6}}{\sqrt{1-\left(\frac{1}{2}\right)^2}} = \boxed{519.61\,m}$$